Docket #71181

REFLECTOR FOR A TIME-OF-FLIGHT MASS SPECTROMETER

FIELD OF THE INVENTION

[0001] The present invention pertains to a reflector, particularly for use with a time-of-flight mass spectrometer as well as a time-of-flight mass spectrometer with a reflector.

BACKGROUND OF THE INVENTION

[0002] Mass spectrometers have been used for several decades for determining the chemical structure of molecules as well as for the quantitative analysis of unknown mixtures of substances. The molecules to be analyzed are usually converted in a mass spectrometer into positively charged particles, the cations, in a so-called ion source. These cations are accelerated from the ion source by means of a constant voltage. The cations are formed under a vacuum, which is as low as possible. They pass through a mass analyzer, in which the ratio of the mass to

the charge is determined. There are a number of different analyzers, e.g., magnetic fields, combinations of a magnetic field and an electric field, so-called double-focusing analyzers, quadrupoles, ion cyclotron resonance cells and time-of-flight mass analyzers. The present invention pertains to a time-of-flight mass analyzer in a time-of-flight mass spectrometer, abbreviated as TOFMS (time-of-flight mass spectrometer). The time of flight of the ions from a predetermined start point to an end point is measured in a TOFMS. Ions with different mass to charge ratios have different times of flight.

[0003] A reflector for a time-of-flight mass spectrometer has been known from, e.g., US 5,955,730. The reflector comprises a plurality of concentrically arranged annular electrodes. The ions are subject to a negative acceleration on their path through the series of annular electrodes. They are reflected and focused in time onto a detector during their flight.

[0004] It is a drawback of the prior-art reflector that the reflector comprises numerous components, which must be arranged exactly in relation to one another. This presents a design effort that is comparatively great.

SUMMARY OF THE INVENTION

[0005] The object of the present invention is to provide a reflector as well as a time-of-flight mass spectrometer with a reflector, with which an electrostatic field is generated that focuses the ions in time in the best possible manner.

[0006] The object is accomplished according to the present invention by a reflector for use in a time-of-flight mass spectrometer as well as a corresponding time-of-flight mass spectrometer.

[0007] The reflector for use in a time-of-flight mass spectrometer has a one-piece design as a radially symmetrical trough in a correspondingly grounded housing. The trough is preferably shaped such that it is flat in a circular area in the middle and has a continuously increasing curvature toward the edge.

[0008] The time-of-flight mass spectrometer has a housing, into which enter the molecules of a gas to be analyzed. The molecules present in the housing are ionized in the housing by means of an ion source and accelerated in the direction of at least one annular electrode, to which a predetermined voltage potential is applied. The ionized molecules subsequently pass through a detector, which is designed, e.g., as an annular disk, and move toward the reflector, which is arranged behind it when viewed in the direction of flight. The reflector is made in one piece as a radially symmetrical trough, and a predetermined voltage potential is likewise applied to it, so that the ionized molecules are deflected hereby in a direction opposite their original direction of flight and finally hit the detector at the end of their travel. The trough-shaped design of the reflector generates a field, which not only deflects the ionized molecules with equal mass to charge ratio but different energies in the opposite direction, but also focuses them in time when hitting the detector.

[0009] A preferred embodiment of the reflector is made of stainless steel or a suitable carrier material with a conductive coating. The interior of the housing of the time-of-flight mass spectrometer is likewise made of stainless steel or a suitable carrier material with conductive coating. The inner side of the trough including the edge of the trough is polished. Precise focusing of the ionized molecules toward the detector is thus especially facilitated.

[0010] In another advantageous embodiment of the reflector, the reflector has a diameter between 60 mm and 75 mm, measured at the edge of the trough.

[0011] Preferred embodiments of the time-of-flight mass spectrometer have a reflector of the different designs mentioned.

[0012] A REMPI (resonance enhanced multi photon ionization) source is preferably used as the ion source of the time-of-flight mass spectrometer. A pulsed laser radiation source releases photons in the ultraviolet range. These photons ionize the molecules of the gas to be analyzed. For example, multi photon ionization sources or electron ionization sources or laser-induced electron ionization sources are conceivably employed as well, according to the invention, for the ion generation.

[0013] Moreover, the detector in the time-of-flight mass spectrometer is preferably designed as a multi-channel plate.

[0014] Due to its comparatively small dimensions, the time-of-flight mass spectrometer can be used as a mobile unit. This is especially advantageous when measurement results must be obtained in a short time, e.g., in the case of the leakage of potentially hazardous materials, if a test sample could undergo changes on its way to the laboratory, or if time and thus money can be saved by the immediate measurement on site. The fields of use of the time-of-flight mass spectrometer according to the present invention are therefore especially gas analyses in military applications, as well as analyses of harmful substances and gas analyses in connection with mobile process monitoring.

[0015] An embodiment of the present invention will be explained as an example on the basis of the drawings. The various features of novelty which characterize the invention are pointed out with particularity in the claims annexed to and forming a part of this disclosure. For a better understanding of the invention, its operating advantages and specific objects attained by its uses, reference is made to the accompanying drawings and descriptive matter in which a preferred embodiment of the invention is illustrated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Figure 1 is a lateral longitudinal sectional view of a time-of-flight mass spectrometer with a reflector.

[0017] Figure 2 is a schematic view of a laser array acting as the so called ion source and directed at a window of the time-of-flight mass

spectrometer housing.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0018] Referring to the drawings in particular, Figure 1 shows a lateral longitudinal section of a time-of-flight mass spectrometer with a reflector (reflector body) 11. The time-of-flight mass spectrometer has a housing 1. The gas to be analyzed spreads in the housing 1. A connection pipe 2 is provided for measuring the pressure in the interior of the housing 1. The connection pipe 2 is located at the upper end of the housing 1. A pump connection 3 is located at the lower end of the housing 1. The pump connection 3 is for evacuating the interior of the housing 1. Aside from the connection 2 and the pump connection 3, the time-of-flight mass spectrometer has an essentially rotationally symmetrical design in relation to the longitudinal axis 4.

[0019] The gas to be analyzed enters the housing 1 from the left (as viewed in Figure 1) through an inlet capillary 5 arranged along the longitudinal axis 4. The inlet capillary 5 extends horizontally to the right and ends at a short distance in front of the repeller 6. The repeller 6 is arranged as an annular electrode at right angles to the inlet capillary 5. The flow of the gas to be analyzed reaches a first annular electrode 7 and then reaches a second annular electrode 8 on the right after the repeller 6 when viewed in the direction of flow. The annular electrodes 7, 8 are arranged in parallel to the repeller 6. The gas entering the housing 1 through the inlet capillary 5 is ionized by means of laser radiation. The laser array 15 is shown schematically in Figure 2. The laser beam 16 reaches the gas present in the housing 1 through a circular inlet window 9 at

right angles of the drawing in the figure. The repeller 6 and the annular electrodes 7, 8 can be adjusted by means of a first screw with fine screw thread 10. The gas molecules ionized by the laser radiation are accelerated by the annular electrodes 7, 8. Pretermined voltages are applied to the annular electrodes 7, 8. The gas molecules ionized by the laser radiation travel along the longitudinal axis 4 in the direction of the reflector 11. The reflector 11 is adjusted by means of a second screw with fine screw thread 12. The reflector 11 likewise carries a certain voltage. The ionized molecules are reflected by the reflector 11 as a function of the geometry of the reflector 11 as well as the value of the voltage applied. A detector 13 is likewise arranged in parallel to the repeller 6 between the annular electrodes 7, 8 and the reflector 11. The ionized molecules reach the detector 13, which is likewise arranged in parallel to the repeller 6 between the annular electrodes 7, 8 and the reflector 11. The distance between the reflector and the detector in the time-of-flight mass spectrometer is indicated as a horizontally extending double arrow. The distance between the reflector and the detector in the time-of-flight mass spectrometer, is, e.g., in the range of 60 mm to 75 mm.

[0020] The laser array 15 shown in Figure 2 is directed at the housing 1 through the circular inlet window 9. The laser array 15 forms a REMPI (resonance enhanced multi photon ionization) source, as the ion source of the time-of-flight mass spectrometer. The pulsed laser radiation releases photons in the ultraviolet range. These photons ionize the molecules of the gas to be analyzed. Multi photon ionization sources or electron ionization sources or laser-induced electron ionization sources may be employed as well, according to the invention, for the ion generation.

[0021] While a specific embodiment of the invention has been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.